Syndicate Report

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Windmills in Antarctica

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1 Introduction

Scott Base, the New Zealand research station on Ross Island in Antarctica was 100% dependent on fossil fuel and diesel generators to satisfy power and heat, until the summer of 2010. To cover this demand, the fuel was bought from the bigger American station, McMurdo, which is next to Scott Base. McMurdo receives fuel deliveries every two years by a big tanker arriving at the station's little port.

Having carried out investigations about wind energy from early 2005 onwards, the decision for three wind turbines on Ross Island was made by Antarctica NZ in April 2008. This joint project with the United States Antarctic Program (USAP) and Antarctica New Zealand is predicted to save almost half a million litres of diesel, reducing the two bases' fuel consumption by 11%. (Vance and Shaw, 2008; IEE, 2008)

Following an environmental evaluation and the permission by the government three turbines were installed in the season 2009/2010. An electrical grid was developed and installed to connect the two bases so that both were connected, resulting in Scott Base and McMurdo benefiting from the renewable energy source. The little wind farm was opened officially on 16 January 2010 and is now producing energy for powering the bases. Further projects are predicted to receive up to 50% of the needed energy from wind are already investigated. (Martaindale, 2006)

But a wind farm in Antarctica? The decreasing dependence on fossil fuels and the new renewable green generators are strong arguments for these projects, but is Antarctica the right place to use them? The Protocol on Environmental Protection (Article 3) of the Antarctic Treaty recognises wilderness and aesthetic values as well as the conduct of scientific research.. The wind turbines stand out more than the bases and can be seen from far in the magnificent landscape. They also have to be anchored in the ground, which disturbs the ground. Should there be a wind farm, or are these three turbines already too much? Can these turbines be justified as a need for science? Or is it a necessary step-in becoming more environmentally friendly in Antarctica? (Protocol on Environmental Protection, 1991)

These questions will be discussed in the following. Arguments for and against the wind turbines will be explained as well as their suitability for Antarctica. The environmental values and the purposes mentioned within the Antarctic Treaty documents will be regarded and compared with turbines as a renewable energy source. Alternatives are considered and in the end a possible conclusion is drawn, as to answer if and how wind turbines should be used in Antarctica.

2 Project Justification

Antarctica New Zealand (ANZ) is a national institution that is committed to the New Zealand's Sustainable Government programme (IEE, 2008). The main drivers therefore are sustainability and the reduction of greenhouse gases. ANZ especially tries to contribute to the following outcomes:

- Promoting a culture of environmental awareness and environmental best practice in all our activities;
- Aiming to run Scott Base as a leading environmentally sustainable small research base in Antarctica; and
- Using more renewable energy, reducing the amount of energy and materials we use (IEE, 2008).

Better independence from the American fuel supply and a more cost efficient way of electric energy supply for the future are also important drivers for wind turbines. This was also the main driver for the USAP joining the project.

While most of the project was financed and carried out by ANZ with Meridian, the American program supplied all necessary logistics for the equipment and personnel as well as needed machinery like cranes at the bases. The project was planned together as it also contributes power to McMurdo. The turbines are planned to power Scott Base, while excessive power will be redirected to McMurdo. For USAP this is seen as a test phase to build ten more turbines if the system works satisfactory, reducing fuel consumption to about 40 to 60%. Without the American Program all these efforts would not have been possible. The connection of the two bases has improved the already good relationship. (Rejeck, 2008; IEE, 2008; Martaindale, 2006)

3 Current Situation

3.1 Scott Base

Scott Base's current annual fuel consumption is around 410,000 litres. This equals a CO_2 emission of 1,090 tons. The total efficiency of boilers and heaters is 70%. From this, 38% go to electrical loads and 32% go to thermal loads. The average power consumption over one year is 150kW. For this about 221,000 litres of diesel are needed. Considering the seasonal power usage, electricity needs in winter are higher than in summer (see Fig. 1). This is especially driven by the fact that 15% to 20% of the total electricity is used by the vehicle hitching rails for heating. (IEE, 2008; Hume, 2005)

The total fuel consumption for McMurdo and Scott Base is ~4.26 million litres of diesel for heating and electricity. The three wind turbines are proposed to produce about 11% of the needed energy which equals 463,000 litres of fuel each year. Considering the reduction of carbon footprint in Antarctica (1,243 tons), Lou Sanson from ANZ said that "this is a significant reduction […] on the world's most pristine continent" (Rejcek, P. 2008).

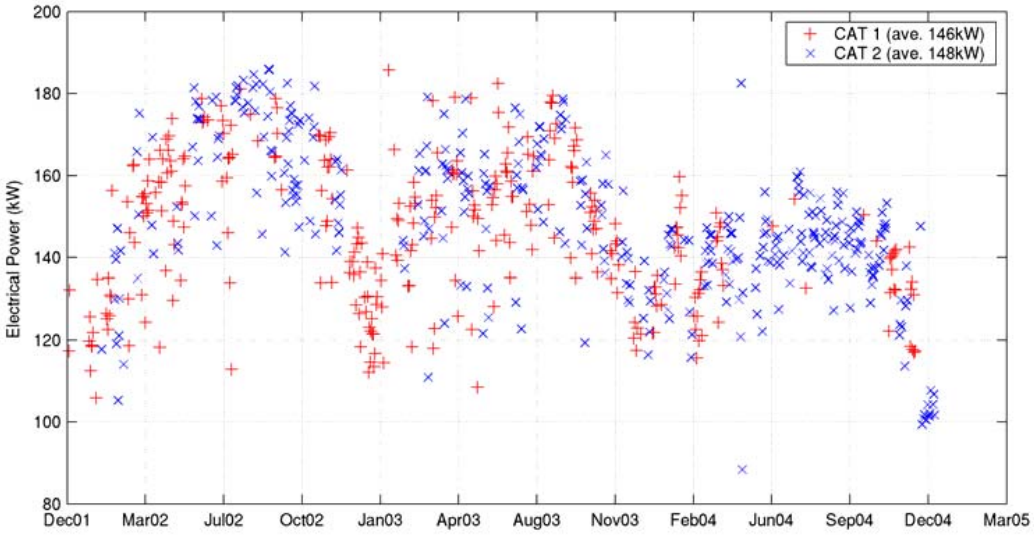

Fig. 1 Trend in Scott Base electrical power production, Dec 2001 to Dec 2004 (Hume, 2005)

3.2 Preparation

For a probable installation of three turbines, the right place had to be found. It should be close to base on already heavily disturbed ground so no new disturbances are created. At the same time it had to be a windy place to get a good efficiency. In general higher areas and ridges are good places for wind turbines. Measurements undertaken around the bases showed that Crater Hill, Arrival heights and the Hut Trail were suitable locations. The Crater Hill site was chosen because it is close to the bases and has already been disturbed by tracks and several antennas.. A longer term automatic weather station (AWS) was installed to receive more wind data. (IEE, 2008)

From the climate records from Crater Hill a suitable turbine type had to be chosen. Regarding the maximum height of the crane a pole height of 38m was chosen. The wind velocity at this altitude is 7.8m/s. To cover the wanted power supply at this wind velocity, three Enercon E33 turbines were chosen. This turbine type is part of the E30 family and already has been installed at Mawson Station, which is the Australian research station. The turbines their were working very satisfactory in the cold environment for the few years.

To make the wind turbines easily removable a special grounding system has been developed. Each turbine is based on eight pre-cast foundation concrete blocks. Each of those weighs 13t and is attached to the ground with two 12m long steel anchors. A sketch can be seen in Fig. 2. As a part of the preparation, the anchors and other foundation equipment was tested on site to assure the suitability. Heavy forces were applied to the equipment, which withstood them without problems proving the possibility of the removable system. (IEE, 2008; Rejeck, 2008)

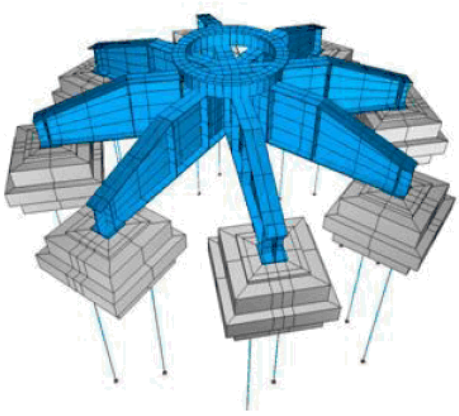

Fig. 2 Foundations of the wind turbines with concrete blocks (grey), anchors and steel structure (blue) (IEE, 2008)

As a last step, an Initial Environmental Evaluation (IEE) had to be prepared. Dependent on the impact this is one of the procedures necessary to fulfil as an Antarctic Treaty Member to get approval for the operation. It was handed in April 2008.

3.3 The wind turbines

Because of the good suitability the Enercon E33 wind turbines has been chosen. The gearless generator allows the turbine to start power generation at lower wind speeds than gear driven generators. With a progressive cut out wind velocity power can be generated even at very high wind velocities up to 34 m/s. An overview of properties can be seen in table 1.

Rated power	330kW
Rotor diameter	33.4 m
Hub height	38 m
Wind class	IEC/NVN IA
Turbine concept	Gearless, variable speed, variable pitch control
Rotor	3 blade upwind with active pitch control
Rotational speed	18-45 rpm
Generator	Direct drive synchronous annular generator
Electrical connection	IGBT AC-DC-AC converter
Cut out wind speed	28-34 m/s (progressive)
Colour of tower/blade	Light grey and non-reflective
Total height when blade is extended	55.2m

Table 1 Properties of the Enercon E33 wind turbines (IEE, 2008; Kettwig H.-D., Wobben, A., 2010)

3.4 Implementation and grid connection

In season 2008/2009 the turbine parts were shipped to Antarctica. Construction on Crater hill started the same year. To connect the turbines to both bases, a connection between the bases had to be installed first. As a first step the bases had to be connected. As McMurdo is using a 4160V/60Hz distribution system and Scott Base is running on 400V/50Hz, the two bases were connected by a converter at Scott Base. The output voltage of 400V/60Hz from the wind turbines is transformed and directly connected to the McMurdo grid. To cover power fluctuations from changing wind velocities, a rotating flywheel power storage was installed. The turbines and generators are controlled by specially developed software to reach the best efficiency of the connected system. An overview over the grid connection can be seen in Fig. 3.

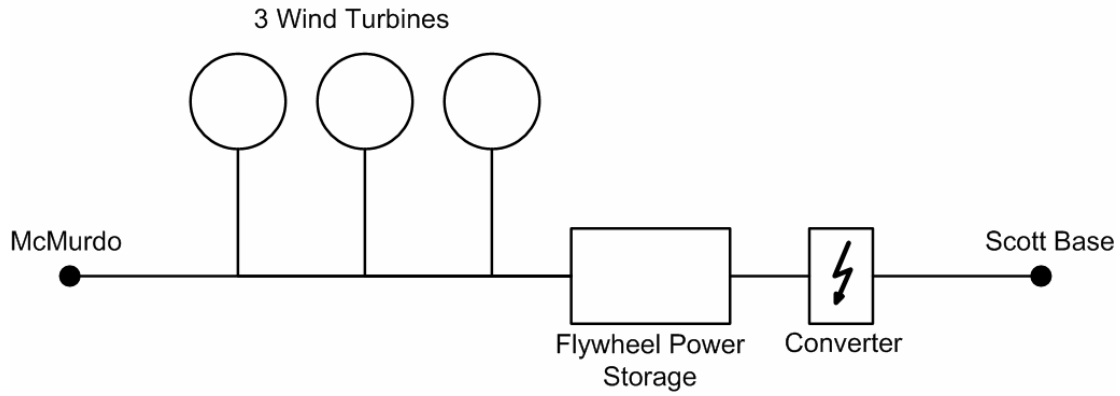

Fig. 3 Overview over the grid connection system

4 Other wind turbines in Antarctica

As we have known, besides Scott Base, there are many other stations that have built wind turbines in Antarctica. Compared to the wind turbines in Scott Base, the other projects are all smaller and create less energy by wind. They are also smaller in size or number and therefore should have less visual disturbance to Antarctica. A lot of bases use wind power to power parts of there equipment. In the following, four bases with major wind turbine sites in Antarctica will be described.

Australian Mawson Station

With two Enercon E-30 turbines, Mason station (see Fig. 4) is able to produce environmentally friendly power via the wind turbines to supply both electricity and heat. The Enercon E30 wind turbine is rated at 300 kW and generates full power at wind speeds above 13 m/s. The average power supply from the wind turbines per year is estimated to be around 480kW (4,200MWh per year), enough to supply 90% of the station's needs for heating, electricity and production of fresh water. The power is also used to generate hydrogen out of water which can be used to power quad bikes with fitted fuel cells. Stored hydrogen can also be used to power heating systems when the wind drops. (Mawson Station, 2010).

Fig. 4 The wind turbine in Mawson Station (Mawson Station, 2010)

Belgium Princess Elisabeth Research Station

Eight Proven 6 kW wind turbines were erected in the Princess Elisabeth research station (see Fig. 5), as well as integrated solar thermal and photovoltaic panels to supplement the wind turbines. The wind turbines can generate approximately 90 MWh per year, which equals an average power of 10kW. This is about two thirds of the station's total annual electricity consumption. The research station is the first zero emission facility in Antarctica which is constructed for an all year round usage. (Traum, M., 2009)

Fig. 5 The wind turbines and Princess Elisabeth research station (Traum, M., 2009)

German Neumayer Station

The wind generator used at Neumayer station (see Fig. 6) is a vertical axis model called HMW 56 and creates power up to 20kW. The turbine produces approximately 35 000 kWh energy per year, an average power outcome of 4kW. This contributes about 6% to the energy needed at the station (El Naggar, S., 2000).

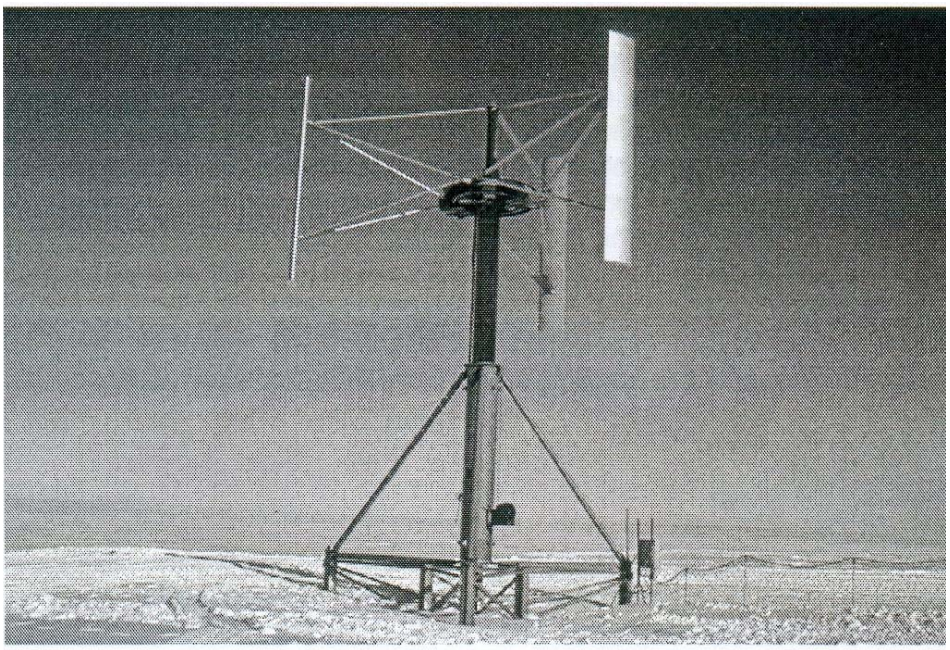

Fig. 6 The wind turbine at Neumayer Station (El Naggar, S., 2000)

Chinese ZhongShan station

Chinese ZhongShan station has installed a 10 kW rated wind turbine. The energy is not stored by utilizing a battery system. It is directly used for the hot water system of the floor heating. It only supplies a small amount of electricity production to the station, but shows the positive effect wind energy can have. (Chinese Antarctic wind turbine, 2010)

Fig. 7 The wind turbine at Chinese ZhongShan station (Chinese Antarctic wind turbine, 2010)

5 Alternative Energies

5.1 Power Generated by the Wind

Wind turbines quite simply turn the power of the wind into usable electricity. Generating electricity by the wind has its impacts on the environment, as do all forms of electricity generation.

Constructing and transporting the turbines requires fossil fuels, electricity and mining for materials. Installing the turbines disturbs a large area of ground, which is important because Antarctica exhibits some of the last untouched ground on Earth. The terrestrial fauna on Ross Island is very sensitive to disturbance. Once the turbines are installed impacts on the environment decline but sound and visual impacts remain. Antarctica's image of a pristine untouched landscape is also affected as the increase in anthropogenic disturbance continues.

Despite this, the need for power at the bases needs to be addressed and wind energy is definitely a valid option, but is it the right one? There are many benefits with wind generation as they are one of the most environmentally friendly forms of generating electricity. Per kilowatt-hour (kWh) wind power occupies less land area than any other energy conversion system, apart from rooftop solar energy (Coleman, 1991). After construction it only takes 3 months of operation to generate the energy used in its construction, yet its operational lifetime is 20–25 years (Coleman, 1991). No greenhouse gases are emitted during operation, although some is emitted during construction, which is compensated for after a few years of wind turbine operation.

5.2 Other energy supplies and their impacts

Geothermal power would be the best option as electricity can be supplied all year round consistently. The geothermal plant could be built at an existing base, with only carbon emissions during construction of the plant. The Dry Valleys Drilling Project drilled in McMurdo, finding that the geothermal gradient isn't large enough to produce the sufficient heat to provide such a power plant (Decker & Bucher, 1982). The gradient is sufficient closer to Erubus (Decker & Bucher, 1982), but the environmental impacts are far too great to justify.

Nuclear Power could provide reliable year round electricity that doesn't produce green house gases. This was even undertaken in on March 3, 1962 where a nuclear power plant was constructed at McMurdo Station. Due to a spill of nuclear waste and public outcry the plant was decommissioned in 1972 (Reid G, 2005). A Nuclear power plant could be a good option

in the future when cheap treatment of nuclear waste is developed. Even so the image of such a plant in Antarctica is strongly opposed by the public so is unlikely to be rebuilt in the near future. It is also currently forbidden in the Antarctic treaty.

Solar power generation comes in two forms, passive (direct heating from sun on dark surface) and active (such as photovoltaics (PV)). Solar heating from the sun to heat water would be a very effective renewable energy supplier as much of the energy used at the bases is in powering the water. Electricity generation from PV panel would also be an environmentally friendly energy option. Both solar options can be strapped to the roofs of existing building causing very minimal impact. The only drawback of this option is no sunlight during the winter months.

Upgrading the insulation of Scott Base, in particular the Hillary Field Center, where the door is commonly open, would decrease the energy consumption of the base. The power of tidal currents, waves and tidal elevation could be harnessed in the future when better technologies are developed.

5.3 Energy Storage

Storing the energy generated by the turbines in high wind events would decrease the need for diesel generators. Current technologies of storage capacity is not sufficient for this purpose, but future technological advancement may make this a valid option. Hydrogen fuel is another energy storage option that can be utilized by vehicles as well. The Hydrogen can be generated from any energy source, so the wind turbines are able to make this fuel. This method is currently in testing stage at Australian Mawson Station (Cellkraft unit operating in Antarctica, 2007). Due to low winds the project has been unsuccessful so far (Cellkraft unit operating in Antarctica, 2007).

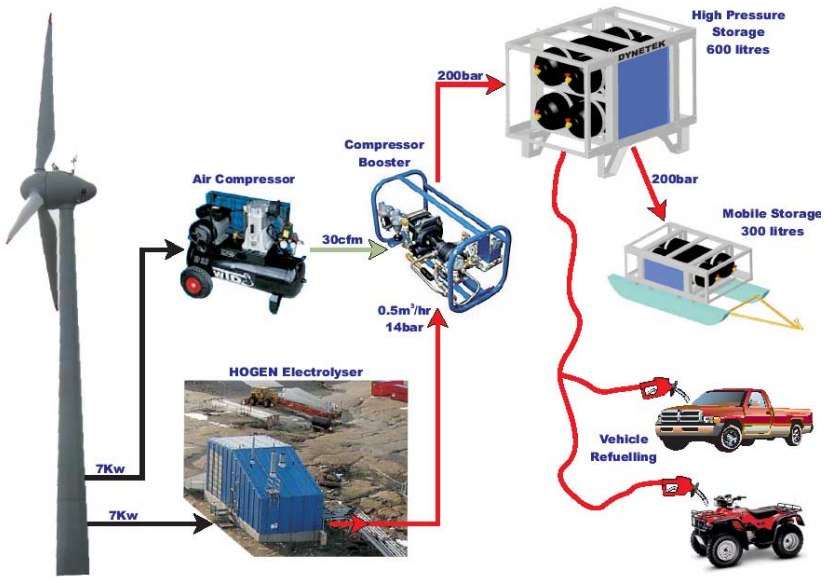

Fig. 8 This diagram shows that the power generated by the wind turbine can be turned into hydrogen fuel that can then be stored and used as an energy supply later. (Courtesy Australian Antarctic Division © Commonwealth of Australia 2009)

To make Scott Base 100% run on renewable energy a mixture of different technologies will have to be applied. Solar energy has low impact and can help to provide energy during the summer months. Wind generation can supply an erratic power supply year round, but could be solved in the future with energy storage. Wind turbines do have a significant visual and ground impact in Antarctica. Insulating the buildings is another cheap low impact method for lowering energy demand, which would be very effective during the winter months. Machines that run directly off fuel, such as automobiles will have to change to different fuel types (eg, hydrogen fuel, electricity).

6 The Treaty system

6.1 The Antarctic treaty – original

The Antarctic treaty originally had 12 Signatories (Antarctic Treaty, 1959). Argentina, Australia, Belgium, Chile, the French republic, Japan, New Zealand, Norway, the Union of South Africa, the Union of the Soviet Socialist Republics, the United Kingdom of great Brittan and Northern Ireland and the United States of America (Antarctic Treaty, 1959). The treaty was signed 1959 and came into force on the 23rd of June, 1961. The main purpose of the treaty was to set aside any conflicts between countries within Antarctica so the continent could be exclusively used for peaceful and scientific purposes (Antarctic Treaty, 1959).

The Antarctic treaty consists of 14 articles. The treaty fails to mention anything about visual or environmental impacts. Article 1 of the treaty states that Antarctica must be used for peaceful and/or scientific purposes, with military presents only to be used for the purpose of science (Antarctic Treaty, 1959). Article 2 of the treaty states that there will be freedom of scientific investigation throughout Antarctica and sharing of information between member countries (Antarctic Treaty, 1959). Articles 1 and 2 of the Antarctic treaty can be interpreted as, any from scientific experiment can be conducted as long as it is not military driven and member countries do not disapprove of the research. Wind turbines can be classed as a scientific experiment as limited knowledge of how much energy will be produced and function in a cold environment still requires a lot of research. Wind turbines can also be classed as a power generating structure with no scientific values.

6.2 Conservation of Antarctic Flora and Fauna

The Conservation of Antarctic Flora and Fauna came into force on November 1 1982. Article 8 in the Conservation of Antarctic Flora and Fauna states that specially protected areas will only be used for scientific purposes with permits (Measures for the conservation of Antarctic Fauna and Flora, 1964). Section 4.b of article 8 states that actions permitted in Antarctic Specially Protected Area (ASPA) will not harm the natural ecological system (Measures for the conservation of Antarctic Fauna and Flora, 1964). .If wind turbines were installed in a proposed area of a ASPA, they may generate more energy than other locations. The ASPA may also be easier to accesses and fewer disturbances may result from the initial installation.

6.3 Protocol on Environmental Protection

The Protocol on Environmental Protection to the Antarctic Treaty came into force on January 14 1998. The protocol provides five specific annexes protecting the Antarctic environment. These annexes focuses on environmental impact assessment (annex 1), conservation of Antarctic Flora and Fauna (annex 2), waste disposal and waste management (annex 3), prevention on marine pollution (annex 4) and area protection management (annex 5) (Antarctic). Another annex was adopted in 2005, which focused on liability arising from environmental emergencies (Protocol for Environmental Protection, 1991). Only annexes 1 and 2 are discussed below as the other annexes do not directly relate to the construction on wind turbines.

Annex 1 is the environmental impact assessment which comprises of three levels. The first level of assessment is the Preliminary Stage, which deals with minor environmental impacts (Protocol for Environmental Protection, 1991). A small field party conducting research for 3 weeks is classified in the preliminary stage. Level 2 is the initial environmental evaluation which deals with moderate disturbances (Protocol for Environmental Protection, 1991). Building a new construction on highly disturbed ground would be classified under the initial environmental evaluation. The erecting of wind turbines at Crater Hill would be classified at level 2. Level 3 is the comprehensive environmental evaluation which deals with large environmental impacts (Protocol for Environmental Protection, 1991). For example, the ANDRILL project is assessed under the comprehensive environmental evaluation as fuel pips could break and leak into the ocean. The wind turbines on creator hill were assessed under the initial environmental evaluation as they were erected on highly disturbed ground. The Australian Mawson base also constructed their wind turbines under the initial environmental evaluation. Situation and classification would be altered under comprehensive environmental evaluation if a biological species had been found.

Annex 2 focuses on the conservation on fauna and flora. Annex 2 sets out to protect all animal and plant life that is agreed on upon by all member countries (Protocol for Environmental Protection, 1991). If any forms of animal or plant life were found where the three wind turbines stand, analysis of the findings would take place to figure out if the area was feasible for construction. As no animal or plant life was found, the turbines were installed reality quickly. Annex 2 sets out to make sure no animal or plan life is brought into Antarctica (Protocol for Environmental Protection, 1991). All the equipment that was transported to Ross Island had to be carefully checked as seeds could easily be transported in with equipment

Initial Environmental Evaluation (IEE)

The Initial Environmental Evaluation created by Antarctica New Zealand sets out to assess the environmental impact of wind turbines being erected on Creator Hill. The three turbines will run year round which is expected to reduce fuel consumed by McMurdo and Scott Base by 11% (IEE, 2008). In 2007 New Zealand passed a bill that stating that renewable energies will be one of their main priorities (IEE, 2008). With this in mind, Antarctica New Zealand outweighed the negatives effects as there were major positive incentives for the construction of wind turbines. The main incentive was the reduction in fossil fuels.

Installation of the wind turbines requires the use of explosives to break up the compact rocks. Explosions created by the dynamite eject debris and dust throughout the area and highly disturbs the ground in a small area. Dynamite was used as it is the best technique with relatively low impact to blast apart the frozen ground (IEE, 2008). Use of dynamite minimized earth-moving equipment in the area, which would have had a greater effect on ground disturbance. Dynamite was also chosen, as it is clean burning (IEE, 2008).

Construction of the wind turbines required a lot of foot and vehicle traffic around Creator Hill. Flora and fauna within the immediate area would have been highly disturbed by the construction. Vehicle movement and ground excavation would have caused the main impact towards the environment.

7 Discussion

In the following, the arguments for and against wind turbines will be discussed. Antarctica's values as well as other concerns arising with wind turbines in Antarctica will be addressed. Furthermore, the possible political reasons are taken under consideration and answers for every argument are tried to be found.

7.1 Image and Political Reasons

Regarding the high publicity on the installation of the wind turbines on Crater Hill, words about being a political campaign often grow loud. It is also discussed if the decision has been pushed by Meridian or Enercon to gain international publicity for being able to install windfarms in Antarctica. Referring to the IEE Protocol this statement is not true. The decision on wind turbines was made by Antarctica New Zealand and several companies and suppliers have been considered as a partner. Meridian was then chosen for already having good experience with wind energy and being a supplier of the German Enercon wind turbines, which are the most suitable for this extreme environment.

The fact that the decision was made because of political reasons to serve New Zealand's green image in the world has to be considered as well. The IEE sais that the contribution to the sustainability program was one of the drivers. Also the lower cost of producing energy at Scott Base in long term has been one reason towards the situation. New Zealand wants represents its values amongst the Antarctic Treaty Members on this beautiful continent. But politics being one reason of constructing the wind turbines at Scott Base does not solve the discussion if they actually serve Antarctica and its values as a pristine environment.

7.2 Ground disturbance

The IEE report quotes that "local terrestrial biota around Scott Base and McMurdo Station have been heavily impacted through physical disturbance over the last 50 years". Thus justify the latest impact of laying the foundations with dynamite for the turbines. The report states that significant patches of moss and lichens species had been observed in 1973 by (Dodge, 1973) but due to disturbance all have disappeared. One reason for this maybe high salinity in the ground, which when turned over by bulldozers or vehicles can become toxic to most plant life (Waterhouse, 2001). It is proposed that it would be "unlikely that much had survived over the last 30 years".

Now that the land has been dynamited, future proposals that are brought forward for more wind turbines will be more likely to be accepted because of this disturbed ground. If this

proposal is accepted, further disturbance would make it more likely for even more turbines and so on.

As already shown, wind turbines do not disturb the ground much more than other normal base buildings. Considering the further disturbed ground, it then is more a question of total base size and number of buildings in the area than a question of if there should be wind turbines. Would, for example, one of the buildings be replaced by a wind turbine, the ground disturbance would stay exactly the same. Therefore, ground disturbance is rather concern that should be addressed to the total base size and the base's management plan than to the fact if wind turbines do any harm to the ground in Antarctica.

7.3 Visual disturbance

New Zealand's initial environmental evaluation (IEE) recognizes that the wind turbines "will have an impact on the aesthetic and wilderness values of Antarctica visually" (IEE, 2008). It also states that due to antennas and towers around Crater Hill, it "will not greatly further diminish the wilderness value of this portion of Ross Island". With these statements, Antarctica New Zealand provided a modelled image of three wind turbines on Crater Hill. Fig. 9 shows this picture with the white wind turbines overlaid by an actual picture taken with the real turbines (grey) in December 2009. At the MTRS2 dome at the right the same size of the pictures is validated. It clearly can be seen that the size of the wind turbines has been underestimated. They are about 30% larger than in the proposal and therefore create a bigger visual impact.

Fig. 9 The overlaid images of the IEE proposal and a real picture

Nevertheless, they only can be seen on clear days as they are covered most of the time in cloudy weather. The fact that the human's view is attracted to movement is causing the high visibility when running. They hardly stand out besides the antennas when not moving. The visibility is assumed to reach up to 10km, but only from certain directions as they are mostly covered by Crater Hill and Observation Hill. Regarding these arguments, the visual impact is increasing slightly, but still could be far worse.

Comparing the turbines to fuel tanks, the visibility of the tanks is also great. The only advantage is that people are very used to the sight of fuel tanks, they are not that high than the turbines and they don't move. However the dimensions of fuel tanks are far bigger than dimensions of wind turbines. So maybe the high visual a bit overestimated as people are just not used to the picture yet. When the turbines can be seen from the distance, one of the bases always will be within the range of vision as well.

7.4 Effect on Science

The effect of wind turbines on science can be recorded with extreme-low-frequency sensors at the ASPA in Arrival Heights. The ASPA at Arrival Heights has been assigned to be magnetically clear for science purposes. These sensors at the ASPA are very powerful and can record lightning strikes all over the world (see red horizontal lines in Fig. 10). The running turbines add a low noise to these signals. That means that the wind turbines' noise can be measured, but it is filter with a program installed for this reason and does not affect results in any way. Therefore can be said that they do emit signals which can be measured but do not influence the results negatively.

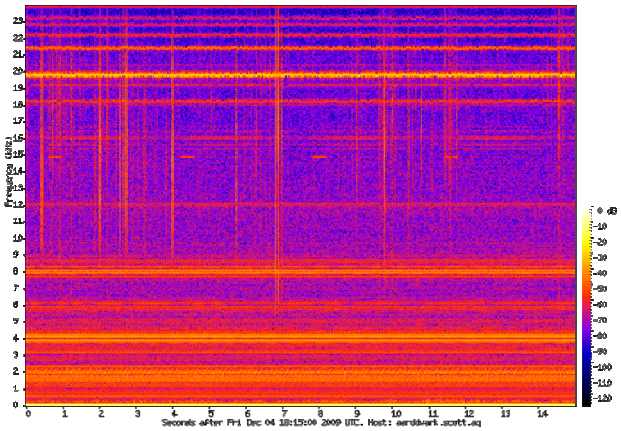

Fig. 10 World Wide Lightning Location Network (Evans et al, 2004)

7.5 Effect on Animals

The initial IEE recognizes that the turbines create noise that cause negligible disturbance.

"The operation of the turbines will add to the general noise created in the area. However, it has been noted that the noise the turbines emit is barely audible and the impact of them on the aesthetic and wilderness values will be negligible. (pg 60)".

The low frequency noise from the wind turbines may affect the Weddell seals, as they are sensitive to these low frequencies (Ray and decamp 1969; Evans et al, 2004). More research is needed to quantify the effects of these low frequencies on the seal population.

For terrestrial animals, the IEE agrees that the cumulative impact on Skua's at Hut Points is still unidentified. Bird strike is possible as the species is attracted to the area by human rubbish near the bases, (Waterhouse, 2001). Accidental bird strike is to be recorded over the next year.

In Mawson, the Australien research station has an average of four bird strikes per year. There is a far bigger bird population at the Mawson Station as breeding grounds are close, bird strikes at Crater Hill are expected to be significantly lower.

7.6 Reduction of carbon emissions

With renewable energy sources like wind turbines, fossil fuels usage can be reduced and therefore exhaust gases and carbon emission. Research that is carried out in Antarctica all points towards the fact that the carbon footprint contributes to climate change. It highly suggests reducing the carbon emissions in the world. Supplying energy to these research projects by burning fossil fuel in Antarctica at the same time casts a damning light on it. Powering the events by renewable energy would be a way better image for science.

7.7 Possible accidents

Wind turbines

Although the wind turbines on Creator Hill are designed for the harsh environment, the possibility of accidents cannot be avoided. In an unlikely event wind turbines do malfunction or get destroyed by natural disasters. For example, wind turbines malfunctioning and catching on fire or getting knocked over in strong winds. If a turbine explodes in Antarctica, it will directly result in air pollution and ground disturbance. Casualties may also occur if humans are present. Clean up operations after turbine malfunction are relatively easy, as debris tends

not to penetrate deep into the soil. Debris can easily be collected, and the turbine structure easily removed. The only issue is removing the foundation of the wind turbine. Removal of the base will create a lot of ground disturbance which not be created if the base stay in the ground. Therefore, if the wind turbines on creator hill are removed, the concrete bases will be left in the ground.

Fossil fuel

Transportation of fuel, transfer and storage create the potential for environmental incidents and impacts. The reduction of fuel transported to Antarctica reduces the risks of oil spills and damage to the environment. As fewer oil tankers are required for refueling Scott Base and McMurdo Station, the chance of an accident occurring is reduced. Although the introduction of wind turbines will not totally replace diesel it does reduce the percentage of error for accidents. If a major fuel spill occurs, clean up can be a costly and difficult task. Severity of the spill will determine the length of the clean up. If a fuel pipe broke and diesel penetrates several meters into the ground, a digger would have to rip all the contaminated soil so it decontamination can occur.

8 Conclusion

Regarding all arguments, it is hard to make a final judgement about the wind turbines at Hut Point Peninsula. The ground disturbance is rather a matter of the total base size than a problem of the wind turbines, as shown in the discussion. Comparing the hazard of accidents to 100% fuel use, the risk can be lowered by using wind turbines. The damage by fuel spills would be far bigger than the damage of malfunctioning turbines. The visual impact is higher than the bases one as the turbines are built on elevated levels and they are higher then most of the other buildings. Nevertheless this only occurs on clear days not being covered by clouds. Despite this fact, humans are quite used to the look of big oil tanks. Danger for animals, especially for birds occurs, but is a very unlikely event due to very few birds in the area. The fact that wind is a renewable energy source, the lowering of carbon emissions can only be a good thing Antarctica. Emissions at Scott Base are far less than anywhere else around the globe, but powering research with fossil fuels creates exhaust gases and carbon emissions which contributes to climate change. Is it moral to conduct climate change research with fossil fuels that add to climate change, this is a debatable issue. As fuel prices will most likely rise in the future wind turbines will be a cost efficient way to produce energy.

Considering the summary of the arguments, a reasonable use of wind energy in Antarctica without expanding the bases seems to be the right way to go. Adding other renewable technologies like solar energy and water heating for peak seasons during summer is an effective way of applying different power supplies and downsize fuel consumption. With the reduction of fuel consumption, carbon emission decreases and a lower risk of accidents go hand in hand.

This gives Antarctica and Scott Base a green image and serves the political intentions of the New Zealand government. However, Scott Base is a New Zealand institution and represents the country in the Ross Dependency. With this dependency, it also represents New Zealand’s values amongst the Antarctic Treaty members. In addition, showing awareness of the environment serves Antarctica and its values as a pristine environment.

It is the time to make changes now. Before the 1950s, the nuclear plant was believed to be a good and clean option until a leakage occurred. In the last fifty years, burning fossil fuels was the way to go until mankind learned about the effects emissions are causing. Therefore, wind turbines and renewable energy seems to be the best way to go to save our planet and Antarctica. This knowledge may change within in the next 50 years and there will be better ways of producing energy then, but for now, this is the best decision. Research in Antarctica should be a good example.

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